STATEMENT OF
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Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to present testimony on the mineralogy and geology of asbestos. My name is Greg Meeker and I am a geologist at the U.S. Geological Survey (USGS) in Denver, Colorado.

Asbestos

Many minerals found in nature grow in a form referred to as ***fibrous***, that is, they possess physical properties similar to organic fibers. ***Asbestos*** is a term applied to a special group of fibrous silicate minerals that form as long, very thin fibers that usually occur in bundles. When handled or crushed, the asbestos bundles readily separate into individual mineral fibers. This type of mineral growth form or "habit" is called ***asbestiform*** (National Research Council, 1984; Skinner and others, 1988). The special properties of commercial-grade asbestos—long, thin, durable mineral fibers and fiber bundles with high tensile strength, flexibility, and resistance to heat, chemicals, and electricity—make it well suited for a number of commercial applications. This definition for asbestos is based on the properties that make it valuable as a commodity. When asbestos regulations were developed in the 1970's it was these commercial fibers that were identified as most problematic from a health perspective because they were the most common species encountered in mining, processing, and manufacturing.

Although there are many asbestos minerals, some commercial and regulatory definitions of asbestos focus on chrysotile, the asbestiform member of the serpentine mineral group, and several members of the amphibole mineral group, including the asbestiform varieties of (1) riebeckite (commercially called crocidolite), (2) cummingtonite-grunerite (commercially called amosite), (3) anthophyllite (anthophyllite asbestos), (4) actinolite

(actinolite asbestos), and (5) tremolite (tremolite asbestos). Other environmental statutes address asbestos more broadly, as other amphiboles are known to occur in the fibrous and/or asbestiform habit (Skinner and others, 1988) but have not been utilized commercially. These include, for example, winchite, richterite (Wylie and Huggins, 1980; Meeker and others, 2003), and fluoro-edenite (Gianfagna and Oberti, 2001; Gianfagna and others, 2003).

Asbestos Mineral Nomenclature

The academic mineralogy community has long classified minerals by name. This mineral nomenclature has evolved dramatically over the years and continues to evolve in response to advances in analytical technology and many other factors. The current academic nomenclature system for amphiboles is endorsed by the International Mineralogical Association (IMA) and recognizes approximately 70 distinct amphibole minerals (Leake and others, 1997). Under this world-recognized system, amphibole minerals are named based on their chemical composition and the exact chemical boundaries between different amphibole minerals are defined on the basis of various mineralogical or other considerations. It should also be noted that in most cases there is chemical gradation (called ***solid solution***) between the different amphibole minerals. That is, there are rarely distinct natural chemical boundaries between the amphibole minerals, only arbitrary boundaries defined by the IMA.

Prior to 1978, amphiboles were primarily identified by optical properties using a transmitted light microscope. This optical identification led to ambiguities and multiple names in the technical literature for the same mineral. In 1978, the IMA's Committee on Amphibole Nomenclature made the decision to redefine amphibole names on the basis of chemical composition and published a classification system that required the use of highly accurate chemical analyses (Leake and others, 1978), with the intent to help reduce these ambiguities. The current amphibole nomenclature established in 1997 is generally similar to the 1978 nomenclature, with the exception that chemical boundaries between several of the amphibole minerals were shifted. In addition to the formal 1978 and 1997 changes in amphibole nomenclature, further confusion results because common and commercial names for some asbestiform amphiboles are still used in some geological or commercial contexts; these include the names amosite, crocidolite, blue asbestos, brown asbestos, and white asbestos.

The "Libby, Montana amphibole" provides an excellent example of the difficulties that have arisen from the co-mingling of different amphibole nomenclatures. During the years that the Libby mine was active, geologists, miners, and regulators called the amphiboles tremolite, soda tremolite, sodium-rich tremolite, and, in one case, richterite. This terminology was used by the geologic and mineralogic communities, as well as by the health, regulatory, and industrial communities. The 1978 IMA change in nomenclature went largely unnoticed or was simply ignored outside of the community of academic mineralogists and geologists, and the Libby amphibole continued to be referred to as a sodium-rich variety of tremolite. Beginning in 2000, mineralogists began to reinvestigate the Libby amphibole and apply the current academic nomenclature, first identifying it as winchite (Wylie and Verkouteren, 2000) and later as winchite, richterite, and tremolite (Meeker and others, 2003). These findings have generated confusion in the asbestos community regarding the identification and nomenclature of the Libby amphibole and whether or not the material is regulated.

Some have taken the position that most of the Libby amphibole is primarily winchite and richterite and therefore is not currently regulated. However, if the nomenclature of Leake and others (1997) is the regulatory touchstone, then the following must also be true. Prior to 1978, all of the Libby asbestos (100 percent) would have been considered to be a form of tremolite and regulated based on the existing nomenclature at the time and the prescribed optical analysis methods for asbestos promulgated under National Emission Standards for Hazardous Air Pollutants (NESHAPs). Between 1978 and 1997 only 15 percent of the Libby asbestos would have been identified as tremolite based on the 1978 IMA system (Leake and others, 1978). Finally, after 1997, due to a mineralogically defined change in the IMA chemical boundaries (Leake and others, 1997), only 6 percent of the Libby asbestos would be classified as tremolite. There is no indication that the regulators intended different treatment for what remained the same underlying substance during this time period. Nonetheless, the Libby amphibole has historically been referred to as tremolite asbestos, and even today could be considered to be a form of tremolite asbestos under the guidelines established for standard Polarized Light Microscopy (PLM) asbestos analysis.

The example above illustrates a subtle but critical point, the Libby amphibole was not originally mistakenly identified as tremolite. The Libby amphibole was correctly identified prior to 1978 as a sodium-rich tremolite based on existing nomenclature and analytical methods. It was also correctly identified as primarily winchite and richterite, after application of the new academic nomenclature using more modern analytical methods. In this example, the IMA inadvertently redefined a regulated material for reasons totally unrelated to asbestos regulation.

Finally, it should be recognized that the nomenclature for amphiboles in the academic community will likely change again in the future (Hawthorne and Oberti, 2006) and new species of fibrous and asbestiform amphiboles may be identified.

Size and Shape of Asbestos Particles

The size and shape of asbestos particles can vary substantially within a single sample and from one sample to another, even if the mineral type is the same. Historically, most commercial asbestos used in products has been chrysotile (Virta and Mann, 1994). Chrysotile tends to have very thin fibers that are often very long and flexible prior to processing. Amphibole asbestos fibers, however, can display a large range of sizes from very long and thin to thick, relatively short, and brittle. A variety of sizes and shapes of amphibole asbestos fibers can occur together and can be inter-grown at the microscopic scale. In addition to the amphibole fibers that fit the commercial definition of asbestos, other amphibole particle types can also occur, again intermixed at the microscopic scale. These other particle types are often referred to by mineralogists as fibrous (non-asbestiform), acicular (needle-like) and prismatic (prism-like) (Meeker and others, 2006). Unfortunately, there are no distinct boundaries between these particle types - they often show a gradation from one to the next in the same sample or material. Also, there is considerable disagreement in the asbestos community about how to distinguish these particle types in a mixed sample and, more importantly, how these different particle types relate to toxicity. These issues were recently raised regarding naturally occurring asbestos in the community of El Dorado Hills California (EPA, 2008; Meeker and others, 2006).

Respirable fibers are those fibers small enough to penetrate into deep lung tissue. (Newman, 2001). Typically, not all fibers or asbestos particles in a material are of respirable size. A soil or aggregate sample containing 0.25 percent respirable amphibole fibers could contain more than 25,000,000 fibers per cubic centimeter. However, larger fiber bundles will continue to generate respirable fibers when disturbed. The degree to which respirable fibers could be liberated into the air by disturbance and become an inhalation hazard depends on many variables including the type of fiber or asbestos, the type of soil or aggregate, moisture content of the soil or aggregate, humidity of the air, and other factors. Therefore, any reliable determination of actual risk by direct measurement of the amount of fibers in the soil or aggregate would be extremely difficult.

Most amphibole minerals encountered in the majority of rock and soil types are not fibrous or asbestiform but occur as larger blocky or massive crystals. When these larger amphibole crystals are crushed or milled they break or "cleave" along specific directions that are related to the crystal structure of the particles. These particles are called ***cleavage fragments***. Cleavage fragment particles are sometimes long and thin and are often difficult to distinguish from the other particle types discussed above.

In addition to the amphibole and chrysotile particles discussed above, other natural minerals exist that can occur as fibrous, or elongated, particles of respirable size. These elongated non-asbestos particles can be referred to as ***elongated mineral particles (EMP)***. One of these minerals, fibrous erionite, has been associated with very high rates of mesothelioma in Central Turkey (Baris, 1978). Fibrous erionite occurrences have been described in some places in the United States (Sheppard, 1996).

Geology of Asbestos

Geologists have documented that asbestos is formed only in specific and predictable geologic settings (Van Gosen, 2007a). The rocks that host asbestos minerals are consistently magnesium-rich (and often also iron-rich) rock types that have been altered in form and composition by metamorphic geologic processes; examples include altered ultramafic rocks and metamorphosed dolomite-rich rocks. In general, asbestos deposits are relatively rare and usually comprise a small volume of the total host rock body. The areas in which asbestos has formed are limited in extent in the United States. The USGS is conducting a study to map the locations of known sites of natural occurrences of asbestos in the United States (Van Gosen, 2005, 2006, 2007b). This work shows that asbestos deposits of various sizes are known to occur in at least 35 of the 50 States. The highest concentrations of asbestos deposits occur in: the eastern States, in a belt stretching from east-central Alabama to Vermont and Maine; the west-coast States of California, Oregon, and Washington; the upper Midwest, in Minnesota and Michigan; and an area of east-central Arizona. This work also shows that significant portions of the United States are **not** geologically likely to have substantial asbestos deposits.

In order to be of commercial value, asbestos must be in sufficient quality and purity for the intended application, and must occur in sufficient abundance to be mined at a profit. In nature, such occurrences are very rare. Far more common is material that can be present in small veins or pods and in quality that can grade from asbestiform to fibrous to acicular to prismatic. The asbestiform component of this material, when undisturbed by human activity, is often called "***naturally occurring asbestos***." As most commonly used, naturally occurring asbestos (***NOA***) refers to asbestos that occurs as a minor to major mineral component in some rocks, soils, sediments or waters as a result of natural geological processes. The term NOA can also apply to asbestos that has been transported by natural weathering and erosion processes from its original geologic source rock into air, soil, sediment or water. (Van Gosen, 2006). Not included in this definition would be commercially processed asbestos-containing materials, such as some insulation and fire protective materials in buildings or some types of automobile brake pads, in addition to soils, sediments, or waters contaminated by commercially-processed asbestos.

In addition, NOA **should not** include asbestos that occurs as impurities in other processed industrial minerals. For example, some products have been made using certain types of talc or vermiculite that contain amphibole asbestos as a natural contaminant (Van Gosen and others, 2004; EPA, 2008a).

Thank you for the opportunity to present this testimony. As a non-regulatory natural science agency, the USGS works closely with other Federal agencies and with non-Federal stakeholders to help answer many important questions regarding the nature of asbestos-related minerals, to develop new analytical methods and procedures for asbestos-related materials, to develop asbestos-related standard reference materials, and to provide important information about where asbestos-related minerals occur in the United States.

I am pleased to answer questions you might have.

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